Title: *Apparent growth rates of pelagic fishes and relationship to abundance* **(2.b.)**

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Summary

We are part way through our examination of trends in and factors affecting apparent growth. We examined length data for delta smelt, striped bass, longfin smelt and threadfin shad collected by the 20mm, Townet (TN), Fall Midwater Trawl (FMWT), Bay Study and Suisun Marsh surveys to determine whether apparent growth rates (i.e., change in mean length across intra-annual sampling intervals) or mean lengths attained by the end of the year changed abruptly during 2002-2004 as compared to previous years., and whether there was a relation between growth rate and abundance.

Though 2002-2004 catches and numbers of length measurements were low for most species and surveys several statements can be made:

1. 2002-2004 apparent growth rates for striped bass, delta smelt and longfin smelt (threadfin shad not well analyzed) do not show a decline as compared to previous years.

2. Annual apparent growth rates for striped bass calculated from Bay Study and Suisun Marsh data are well correlated ($r = 0.775$, $p<0.02$, 9df), lending some support to their use to discriminate changes over time.

3. There was no apparent decline in length attained by the end of the first year for years 2002-2004 to indicate growth of survivors has been impacted recently.

Introduction

Fish growth rates can be an indicator of toxic exposure or food limitation and year-end size may be related to winter survival, and in the case of delta smelt females, potential fecundity. Spawning is delayed and the striped bass index (i.e., the date when age-0 population surpasses 38 mm) is set later in years of low water temperature and high flows (Miller 2000); temperature influences delta smelt spawn timing too, by either delaying onset or prolonging the 14-18˚ spawning window (Fleming per. com.). Such delays may reduce growth and end-of-year size, possibly reducing winter survival, or in the case of delta smelt fecundity. Sweetnam (1999) noted a step decline in mean length of delta smelt caught by the FMWT that started in about 1990. Townet and FMWT length data have not been analyzed for other species or for recent-year effects. This analysis may be particularly useful for striped bass because the approximate date that the population reached an average length of 38 mm is known from the TNS (Turner and Chadwick 1972). Thus, fall striped bass length distributions may be corrected for spawn timing or other factors that influence early larval growth and/or individual length at a particular time (Miller 2000). We assess whether similar methods are suitable for delta smelt. We also plot growth rates and abundance to examine this relationship.

If pelagic fishes were exposed to sub-lethal toxics or food limitations during 2002-2004 as compared to previous years, we would expect to see generally slower growth rates and fishes attaining smaller sizes at the end of first year's growth in the FMWT. Currently we provide growth rates and end-of- year size trends as indicators of potential stressors in the environment (e.g., low food availability, contaminants).

Methods

Data

We compiled length frequency data for delta smelt, striped bass, longfin smelt and threadfin shad captured by five surveys: 20 mm, Townet, FMWT, Bay Study and Suisun Marsh. All measurements are in mm fork-length (FL) taken in the field, or in the case of Suisun Marsh data, converted to mm FL from standard length based upon the relation:

FL=0.328+(1.128*SL)

Surveys initiated to target striped bass, Townet and Fall Midwater, did not begin consistently measuring other fishes until about 1972 and mid 1975 respectively. The Bay Study, Suisun Marsh and 20mm surveys have measured all or a random subset of each species from each sample since their inceptions in 1980, 1980 and 1995, respectively. For current purposes, Townet data analyses were limited to striped bass and delta smelt data collected after 1972. Beginning in 1992, TNS and FMWT protocols changed and 50 randomly selected individuals were measured from each sample in addition to all the striped bass and delta smelt. When species catches (other than striped bass and delta smelt) were high, a randomly selected subsample of each species was measured and assumed representative of the length distribution of the entire sample. When only a portion of the species catch was measured, frequency at length was adjusted upward by the proportion total catch/total measured (denoted adjusted frequency).

The utility of townet data was limited historically by the high frequency of only two sampling surveys per year, and more recently by low catches and highly variable progression of size modes.

Analyses

Species apparent growth rate was estimated by the change in the arithmetic mean length across two or more intervals of time in days. Two methods were used. First, a rough approximation of growth for striped bass and delta smelt was derived from TNS and FMWT data as the quotient of the difference in survey mean-lengths (mm) over the Julian day difference in survey mid-points. We used the interpolated dates when striped bass reached a mean length of 38.1 mm in the TNS and the mean survey length and survey mid-point for September FMWT (or August if sampling started early). For delta smelt, the length and date data were derived as the mean length and the mid-point date for Townet survey 2 for each year.

A second apparent growth rate approximation was derived by regressing monthly mean lengths on Julian date across three or more time intervals, where an interval may be fortnightly (20mm Survey) or monthly (FMWT, Bay Study, Suisun Marsh). Dates representative each sampling interval were selected either as the mid-point of survey (20 mm and FMWT) or the mid-point of dates when most striped bass were caught within a survey (Bay Study and Suisun Marsh).

Length measurements used for analyses were constrained to a single year-class for each year for all species except threadfin shad where one or two year-classes might be present. Two methods were used to derive means for species length: 1) straight calculations based on selection of temporal grouping categories; or 2) length frequencies grouped into 3-5 mm intervals were examined in FiSat II (http://www.fao.org/fi/statist/fisoft/fisat/index.htm), modes approximated and means calculated using the NORMSEP routine. Some biological judgment was used in selecting successive means across time to use for simple linear regression analysis of growth.

Finally, monthly and annual mean lengths were calculated and plotted from FMWT data to examine whether growth continues through late fall and winter, and to represent the size attained at the end of the growing season (year-end mean size).

Results

Spring-summer growth rates for delta smelt from the 20mm survey tended to be a little higher after 2001 than before, whereas longfin smelt rates appeared to increase and remain relatively high starting in 1999 (Figure 1). There was no consistent pattern of low growth after 2001.

Post – 1992 striped bass growth rates, calculated as a difference in mean size at date for TNS and FMWT fish, ranged from 0.61 to 2.1 mm/day; a sharp drop occurred between 1999 and 2000, but rates after 2001 went up slightly (Table 1; striped bass 1st column). A similar pattern of decline occurred for delta smelt, though the sharp drop occurred between 1997 and 1998 and rates climbed somewhat in 1999 and fluctuated thereafter (Table 1; delta smelt 1st column).

Bay Study and Suisun Marsh Survey striped bass growth rates were well correlated with one another (Figure 2, Table 1; $r = 0.77$, $p<0.01$, 9df) and almost a one to one slope (0.93). Growth rates were generally higher after 2001 than before for striped bass from both surveys.

Fall-winter growth rates tended to be higher post-2001 for striped bass and threadfin shad, and within the pre-2001 range for delta smelt (Table 1; striped bass 4th column; delta smelt 2nd column; threadfin shad 1st column). The former two species appear to continue to grow September through December, whereas delta smelt generally did not (Figure 3).

Year-end mean size for delta smelt declined between 1989 and 1993 and has fluctuating at a lower level since (Figure 4A). This is consistent with the pattern identified by Sweetnam (1999). Striped bass year-end mean sizes fluctuated broadly and tended to increase through the sampling period, but exhibited a distinct upturn from 2001 through 2004 (Figure 4A). Longfin smelt have shown several cycles of year-end size with local lows in 1982, 1995 and 1999 (all high abundance years; Figure 4b). Since 2001 year-end sizes for longfin smelt have been relatively high. Threadfin shad have fluctuated widely in year-end size, but with the exception of year 2000, sizes since 1992 have been low, and those since 2001 moderate and declining (Figure 4b).

Conclusions

None of the methods used suggested a decline in growth rate or year-end size after 2001. On the contrary, growth rates were generally as good or better during the 2002-2004 period.

End of the year size for delta smelt declined in the late 1980s coincident with the establishment of *Corbula amurensis* and has not recovered. Striped bass end of year size appears to have increased substantially since the cool, high outflow year 1998 set back spawning resulting in the most recent low year-end mean size. Current low catches of striped bass in the FMWT make recent mean size estimates uncertain.

Personal Communications

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References

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Turner, J. L. and H. K. Chadwick. 1972. Distribution and abundance of young-of-the-year striped bass, *Morone saxatilis*, in relation to river flow in the Sacramento-San Joaquin Estuary. Transactions of the American Fisheries Society 101: 442-452.

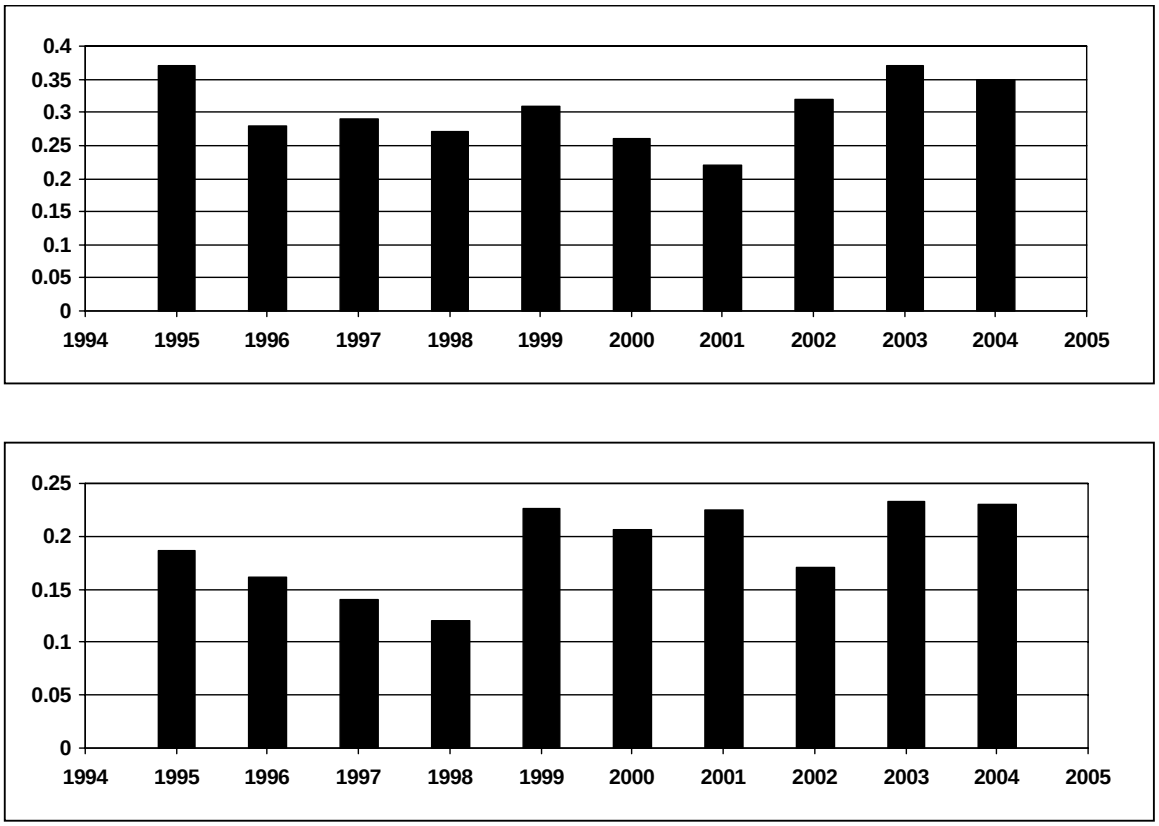

Figure 1. Apparent growth rates (mm/day) for delta smelt (Top) and longfin smelt (bottom) captured by the 20mm Survey, 1995-2004.

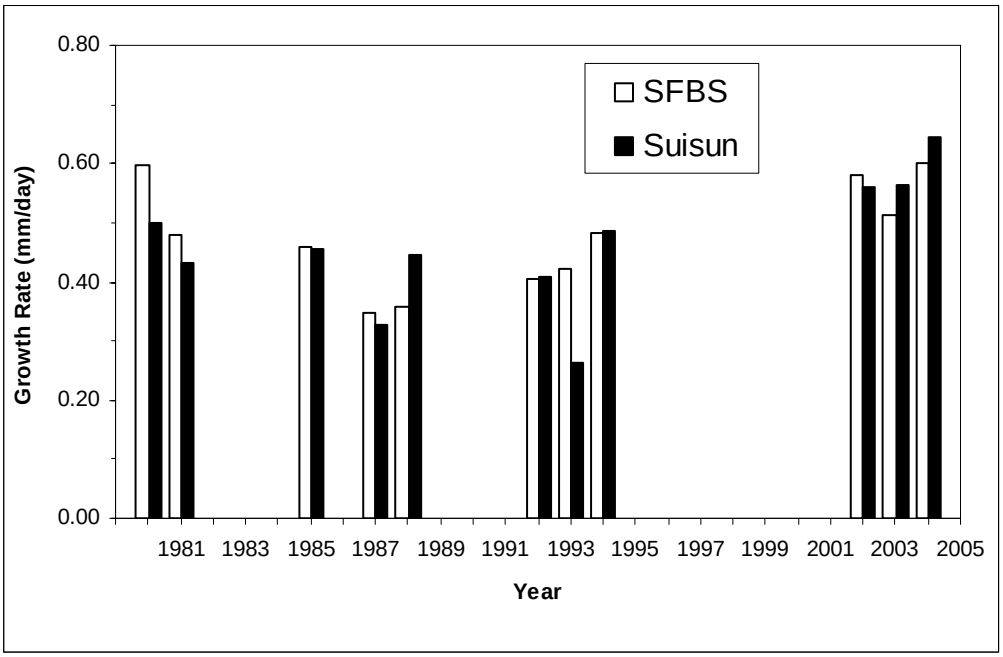

Figure 2. Apparent growth rates (mm/day) for striped bass captured by the San Francisco Bay Study otter trawl (SFBS) and the Suisun Marsh Survey otter trawl for selected years 1980-2004.

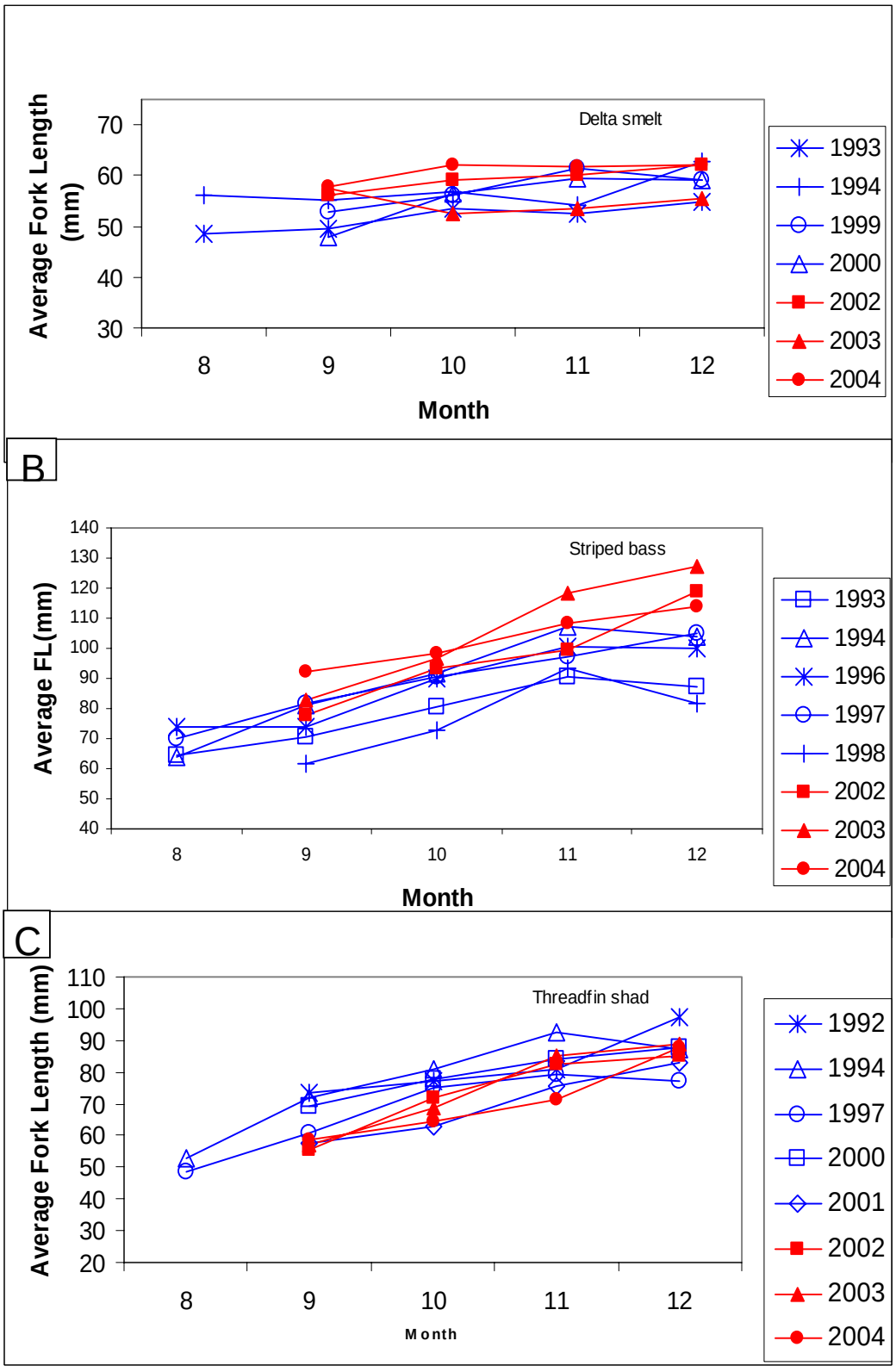

Figure 3. Mean length (mm FL) by month for delta smelt, striped bass and threadfin shad captured by the Fall Midwater Trawl for selected years 1992-2004.

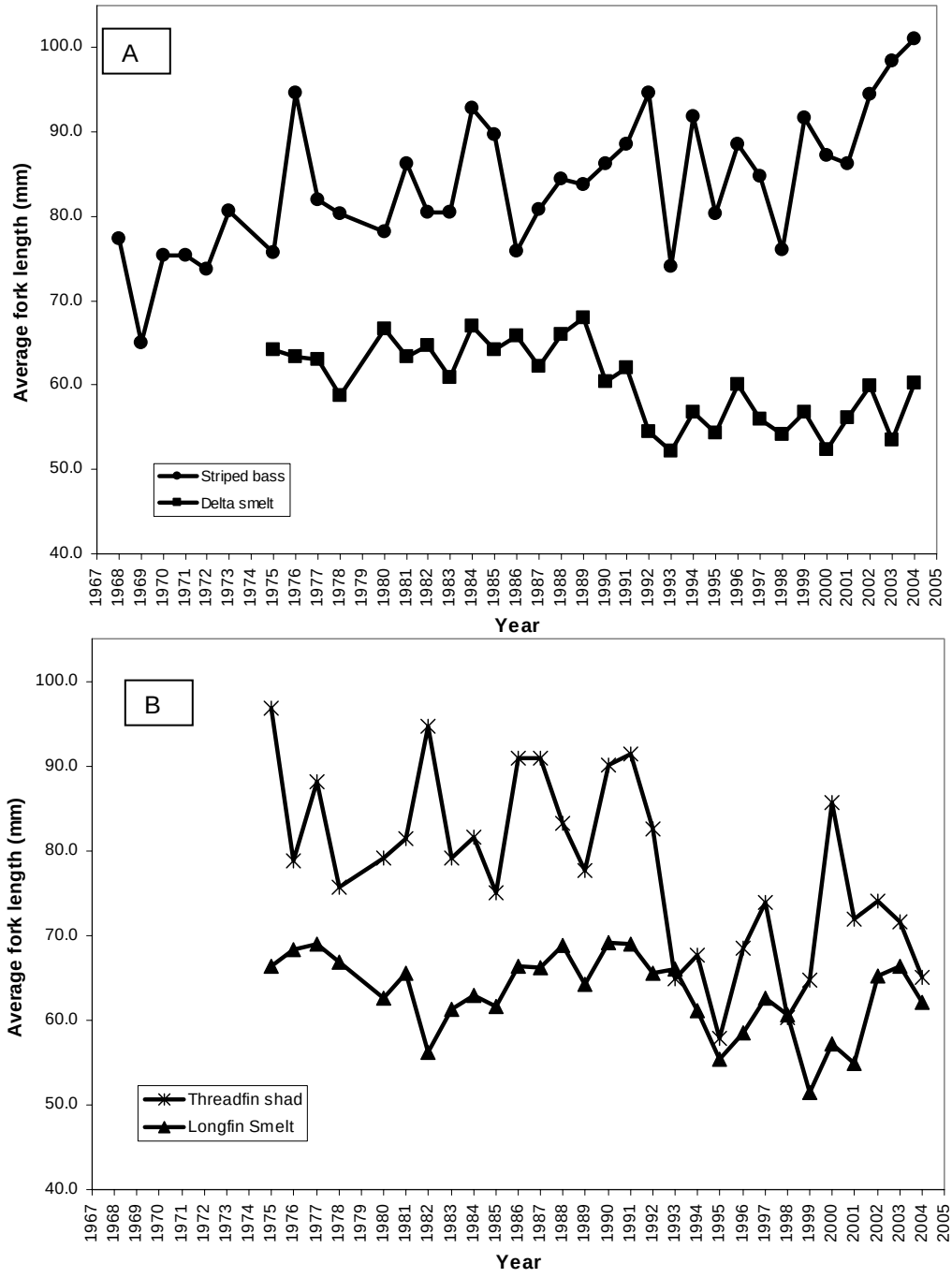

Figure 4. Mean length (mm FL) attained at year's end for delta smelt, striped bass (A) longfin smelt and threadfin shad (B) captured by the Fall Midwater Trawl for selected years 1992-2004.

Table 1. Growth rates (mm/day) for striped bass, delta smelt and threadfin shad estimated from mean size by date from the Townet, Fall Midwater Trawl, Bay Study and Suisun Marsh surveys, 1980-2004.

	Striped Bass				Delta Smelt		Threadfin Shad
Year	Summer - Fall (TNS-FMWT)	Summer-Fall (Bay Study)	Summer-Fall (Suisun Marsh)	Fall-Winter (FMWT monthly to daily)[1]	Summer - Fall (TNS-FMWT)	Fall-Winter (FMWT monthly to daily)[1]	Fall-Winter (FMWT monthly to daily)[1]
1980		0.5958	0.5011				
1981		0.4788	0.4315				
1982							
1983							
1984							
1985		0.4577	0.4573				
1986							
1987		0.3460	0.3272				
1988		0.3564	0.4448				
1989							
1990							
1991							
1992	0.609	0.4067	0.4080		0.156		0.248
1993	1.205	0.4213	0.2634	0.218	0.282	0.053	
1994	0.963	0.4817	0.4870	0.351	0.461	0.041	0.3
1995					0.278		
1996	2.1			0.264	0.759		
1997	1.28			0.286	1.02		0.253
1998	1.185			0.266	0.11		
1999	1.076				0.272	0.081	
2000	0.647				0.182	0.125	
2001	0.609				0.272		0.294
2002		0.5812	0.5588	0.436	0.242	0.065	0.332
2003	0.949	0.5126	0.5635	0.518	0.308	-0.016	0.371
2004	0.806	0.6011	0.6452	0.249	0.259	0.042	0.311

[1] Growth generally slowed to almost zero during this period -- at the start for Delta smelt and toward the end for striped bass and threadfin shad -- and catches were low in the 2000s so sampling variability had a slightly larger influence growth rate.